Resource Action: EWG-36 **Task Force Recommendation Category: 2**

Operate the Oroville Facilities to Provide Additional Cold Water in the Low Flow Channel of the Feather River for Benefit of Chinook Salmon and Steelhead

Description of Potential Resource Action Measure:
This measure proposes to change operations of the Oroville Facilities to reduce water temperatures in the low-flow channel of the Feather River (LFC) during certain times of year for the benefit of Chinook salmon and steelhead. The changes in operation would likely include releasing colder water from the reservoir and increasing releases to the LFC.

Date of Field Evaluation: No field evaluation was conducted

Evaluation Team: Phil Unger, review by Brad Cavallo and Mike Manwaring

Related Resource Actions:
Other Resource Actions that are either similar to or otherwise related to this measure include:

- EWG-34A and EWG-34B, which propose to reduce rates of fish predation on juvenile salmonids by reducing water temperatures.
- EWG-37, which proposes to operate the Oroville Facilities in a manner that would provide colder water in Feather River downstream of the Thermalito Afterbay river outlet for benefit of Chinook salmon and steelhead.
- EWG-87, which proposes to modify the Thermalito Complex facilities in a manner to increase water temperatures in the Thermalito Afterbay and reduce temperatures in the Feather River downstream of the Afterbay outlet for beneficial uses.
- EWG-102, which proposes to provide water temperatures in the lower Feather River that mimic historic (pre Oroville Dam) river temperatures to help maintain the genetic integrity of the spring-run Chinook salmon.
- EWG-27, which proposes to fill, modify, or isolate Robinson Riffle Borrow Pit.

Nexus to the Project:
Water temperatures in much of the lower Feather River are strongly affected by operations of the Oroville Facilities. The Oroville Facilities allow project operators to regulate the depth in Oroville Reservoir from which water is released, the amount of water released from the reservoir into the river, the amount of water diverted from the LFC of the river through the Thermalito Complex, and the amount of water pumped back into the reservoir from the Thermalito Complex. These operational controls give the operators various degrees of control over water temperatures in the LFC.

The 1983 agreement between DWR and DFG, Concerning the Operation of the Oroville Division of the State Water Project for management of Fish & Game, established quantitative water temperature criteria for the lower Feather River. In this agreement, the Oroville Project is required to meet quantitative water temperature criteria at two downstream locations: the Feather River Hatchery (FRH) and the LFC at Robinson's Riffle (River Mile 61.6). Generally speaking, the FRH water temperature criteria serve as the controlling water temperature targets because the Robinson's Riffle criterion is usually satisfied whenever the FRH criteria are met. The FRH criteria vary over the course of a year as shown in the following table:

Period	Temperature (+/- 4°F)
April 1 – May 15	51°
May 16 – May 31	55°
June 1 – June 15	56°
June 16 – August 15	60°
August 16 – August 31	58°
September 1 – September 30	52°
October 1 – November 30	51°
December 1 – March 31	55°

Table 1. Feather River Hatchery Water Temperature Requirements from Oroville Project Operations.

Deviations in FRH water temperature of 4^{o}F above or below the FRH criteria are allowed. The Robinson's Riffle criterion is a daily average water temperature less than or equal to 65^{o}F from June 1 through September 30.

Potential Environmental Benefits:
As formulated by the EWG, this Resource Action would most likely be implemented from April through October. This period includes the rearing period for spring-run Chinook salmon and steelhead, and the immigration, holding and spawning period for spring-run Chinook salmon.

The water temperatures in the upstream end of the LFC are generally determined by the FRH temperature requirements. During June 1 through September 30, water temperatures at Robinson' Riffle are regulated by the Robinson's Riffle criterion. Water temperatures in other parts of the LFC are determined by whatever warming or cooling occurs in the LFC as the water flows downstream from the Fish Barrier Dam and/or Robinson's Riffle. During late spring and summer in 2002 and 2003, water temperatures in the LFC warmed a maximum of about 7^{o}F between the most upstream portion of the LFC and Robinson's Riffle (about 5.5 miles downstream of the Fish Barrier Dam) and warmed an additional couple of degrees before reaching the Thermalito Afterbay outlet, about 8 miles downstream of the Fish Barrier Dam (Figures 1 and 2). Patterns of warming were similar from month to month within each year. In 2003, the most rapid warming occurred in the long reach from about one mile downstream of the Fish Barrier Dam to Robinson's Riffle, which is dominated by pools, and in the final one-mile reach that is dominated by the Thermalito pool and other pools (Figure 2). In 2002, warming was generally more constant over the length of the LFC

(Figure 1). Maximum daily average water temperatures were higher at all locations in the LFC during June, July and August than in other months (Figures 3 and 4) (Note that the very high temperature value for October at Eye Riffle likely represents a temperature logger malfunction or exposure to the air). The June, July and August maximum water temperatures at Robinson's Riffle, Eye Riffle and the site upstream of the Afterbay outlet ranged between about 63.5 and 67.5^{o}F. The maximum temperatures at Auditorium Riffle (about 1 mile downstream of the Fish Barrier Dam) ranged up to only about 61^{o}F. The mean daily average water temperatures, while consistently lower then the maximums, exhibited similar patterns of variation to the maximums (Figures 5 and 6).

The EWG fisheries team determined Chinook salmon and steelhead water temperature needs for each lifestage by synthesizing information obtained from the fisheries literature. Both fall-run and-spring run Chinook salmon spawn in the LFC beginning in early September. The EWG team determined that spawning and egg incubation water temperature requirements for Chinook salmon are no more than 56^{o}F or 58^{o}F (the two values reflect minor differences in the set of literature sources used for deriving the critical temperature estimates). During 2002 and 2003, the mean September water temperatures at Robinson's Riffle and locations downstream ranged from about 56 to 59^{o}F (Figures 5 and 6), and the maximum September temperatures ranged from about 59 to 61^{o}F (Figures 3 and 4). These results indicate that a modest reduction in water temperatures during September would improve spawning conditions for the salmon in the lower part of the LFC. At Auditorium Riffle, both mean and maximum water temperatures were well below the temperature requirements.

Steelhead begin spawning about December, but continue spawning until approximately April, and egg incubation can continue through May. The EWG fisheries technical team determined that spawning and egg incubation temperature requirements for steelhead are 52^{o}F and 54^{o}F (again, the two values reflect differences in the set of literature sources used for estimates). From April 1 through May 15, the FRH water temperature criterion is 51^{o}F, and from May 16 through the end of May the criterion is 55^{o}F. During 2002 and 2003, the mean and maximum daily average water temperatures at the three downstream locations in the LFC were consistently higher than the steelhead spawning and egg incubation temperature requirements (Figures 3 through 6). At the upstream location, the maximum temperatures, but not the mean temperatures, exceeded the requirements. Therefore, reducing water temperatures in April and May would likely benefit steelhead.

Implementing the Resource Action during the summer months could benefit spring-run and fall-run Chinook salmon. Spring run adults hold in pools in the LFC from late spring through summer. Fall run migrate upstream in late summer and hold more briefly. The EWG fisheries technical team determined that upstream migration and holding temperature requirements for adult spring-run and fall-run Chinook salmon are 60^{o}F and 64^{o}F (as before, the two values reflect differences in the set of literature sources used for estimates). The 2002 and 2003 mean June through August water temperatures at Robinson's Riffle and locations downstream ranged from 61 to 65.5^{o}F, and the

maximum June through August water temperatures at these locations ranged from 63.5 to 67.5^{o}F. Therefore, reducing the June through August water temperatures would likely benefit migrating and holding Chinook salmon, particularly spring-run Chinook salmon. The 2002 and 2003 mean and maximum water temperatures at Auditorium Riffle were generally suitable for Chinook salmon migration and holding. Note that the relicensing study, SP F10, Task 1E, concluded that summer water temperatures in the upstream portion of the LFC near the Fish Barrier Dam are suitable for spring run holding, but water temperatures in the downstream portion of the LFC are generally not consistently suitable for spring run.

Potential Constraints:
The most immediate potential constraint on this measure is the requirement to meet the FRH water temperature criteria. However, because the reductions in water temperature required for this measure would not be large, this potential constraint would probably rarely actually affect the implementation of the Resource Action. A more significant potential constraint on this measure is the limited volume of Oroville Reservoir's cold-water pool. The limited amount of cold water available in the reservoir restricts how much, and for how long water temperatures in the LFC could be reduced. This constraint would likely be significant only in dry and/or critically dry water type years. Another important constraint is the loss of generation that would likely accompany implementation of the measure. Operations that can be used to reduce water temperatures in some or all of the LFC include increasing flow releases to the LFC, reducing pump-back and peaking operations, and opening the Oroville Dam river valve. These actions would typically result in losses in hydroelectric power generation. This measure could also be constrained by regulatory requirements. The narrative objective for water temperatures in the Feather River below the Thermalito Afterbay river outlet requires water temperatures that are suitable for shad, striped bass and other warmwater species from May through August. Reducing spring and summer water temperatures in the LFC could make it difficult to meet this objective. Finally, measures to reduce water temperatures in the LFC are potentially constrained by the goal to supply rice farmers with warm water during spring and summer and by the goal to provide suitable warm water for recreation activities.

Existing Conditions in the Proposed Resource Action Implementation Area:
The LFC is situated downstream of the Oroville Dam, extending eight miles from the Fish Barrier Dam to the Thermalito Afterbay outlet. The average monthly water temperatures in the LFC near the Fish Barrier Dam typically range from about 46°F in winter to about 58°F in summer. Water temperatures typically drop sharply from August to September (see Figures 3 through 6), largely because the FRH water temperature criterion for September is much lower than that for late August (52^{o}F vs. 58^{o}F). As noted previously, water temperatures typically rise by no more than about 7^{o}F between the Fish Barrier Dam and Robinson's Riffle, and increase another 2^{o}F before reaching the Thermalito Afterbay outlet. Back flow from the Thermalito Afterbay outlet and warm

water released from Robinson Pond probably contribute to warming summer water temperatures in the most downstream mile or two of the LFC.

Because of the influence of warm water inflow from the Thermalito Afterbay outlet, water temperatures in the Feather River just downstream of the outlet are often several degrees warmer than temperatures in the lower part of the LFC, particularly in the late spring, summer and early fall. This change in water temperature may be stressful for migrating fishes, but also elevates predation risk because of the increased abundance of piscivorous bass and Sacramento pikeminnow.

Design Considerations and Evaluation:
Engineering and Operations water temperature modelers are currently evaluating effects of different project operations on water temperatures in the LFC. Results of the modeling simulations will be used to develop specifics of how project operations could be modified to implement this Resource Action.

The effectiveness of this measure would be evaluated by comparing water temperatures measured at several locations in the LFC before and after implementing the measure. The comparisons would use water temperature modeling to adjust for differences in atmospheric conditions and other potentially confounding variables in making the comparisons. Water temperature data currently being collected in the LFC will provide the information on water temperatures before implementing any changes in project operations.

Synergisms and Conflicts:
This Resource Action is compatible with Resource Actions EWG-37 and EWG-102, which share with EWG-36 the resource goal of providing desirable water temperatures for coldwater fish. By benefiting coldwater fishes, the Resource Action would likely enhance recreation in the LFC, providing increased summer angling opportunities for trout and Chinook salmon. This Resource Action would likely improve habitat conditions for anadromous salmonids and upstream passage through the fairly steep thermal gradient at the end of the LFC, which are resource goals of many of the proposed resource actions. The colder water that would result from this resource action might also help reduce predation on juvenile salmonids in the Thermalito Pool, upstream of the Afterbay outlet, because colder water in the Pool would reduce metabolic rates of the fish predators in the Pool, and thereby potentially reduce their feeding rates. Reduced predation on juvenile salmonids, which is the basis for Resource Actions EWG-35A, EWG-35B and EWG- 27.

This Resource Action would potentially conflict with a number of resource goals. These include providing warmer water to Thermalito Afterbay for agriculture (e.g., EWG-87), increasing production of coldwater fishes in the reservoir, and enhancing water contact recreational opportunities in the lower Feather River. Depending on the methods used to reach desired temperatures, this resource could also have considerable costs in terms of lost power generation. However, to the extent that more water is diverted

through the LFC rather than through the Thermalito Complex this resource action also has the potential to allow warmer waters for agricultural diversion from the Thermalito Afterbay (EWG-87).

Uncertainties:
Important uncertainties related to this measure include:

- Whether the amount of water in Oroville Reservoir's cold-water pool during dry and/or critically dry years would be sufficient to effect the proposed reductions in water temperatures, particularly during late summer and fall, and how a reduction in the volume of the cold-water pool would effect the cold-water fisheries of the reservoir.
- Whether the Resource Action could be implemented without conflicting with DWR agreements or goals, including the FRH water temperature criteria, the goal to provide suitable water for the needs of rice farmers, and the agreement to provide water temperatures downstream of the Thermalito Afterbay outlet from May through August that are suitable for shad, striped bass and other warmwater species.
- The amount of revenue that would be lost because of changes in power generation.

Cost Estimate:
The principle cost of this measure would be lost revenues associated with the changes in power generation (including reduced generation and changes in generation peaking). Additional costs would come from water temperature monitoring to evaluate the effectiveness of the measure and to ensure compliance with any new water temperature requirements.

Recommendations:
Before implementing this measure, better information is needed from water temperature modeling simulations. These evaluations should provide useful insights on the feasibility of the measure in light of the potential conflicts and limitations.

Figures

Figure 1. Water Temperatures in LFC during Days of Maximum Warming, 2002

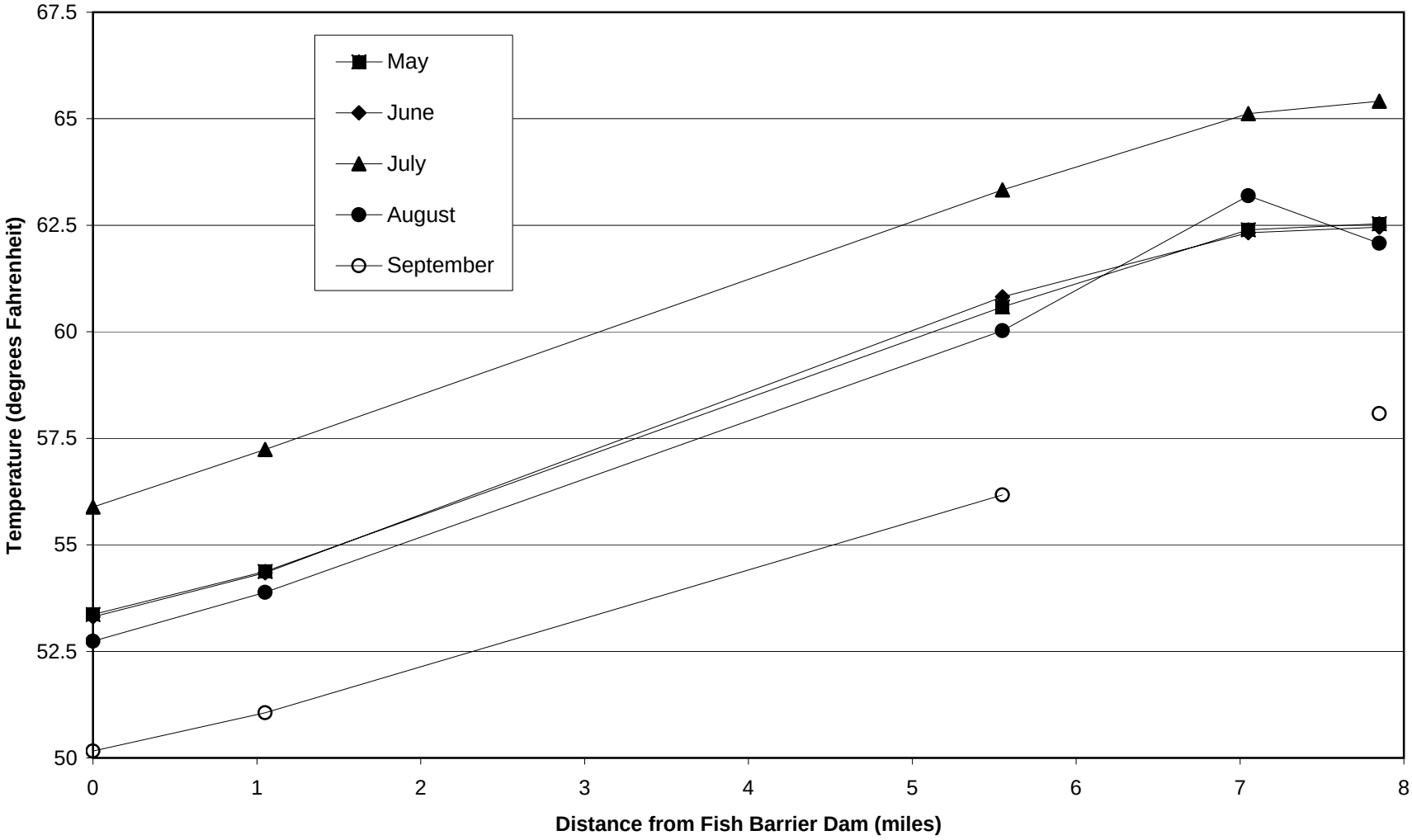


Figure 2. Water Temperatures in LFC during Days of Maximum Warming, 2003

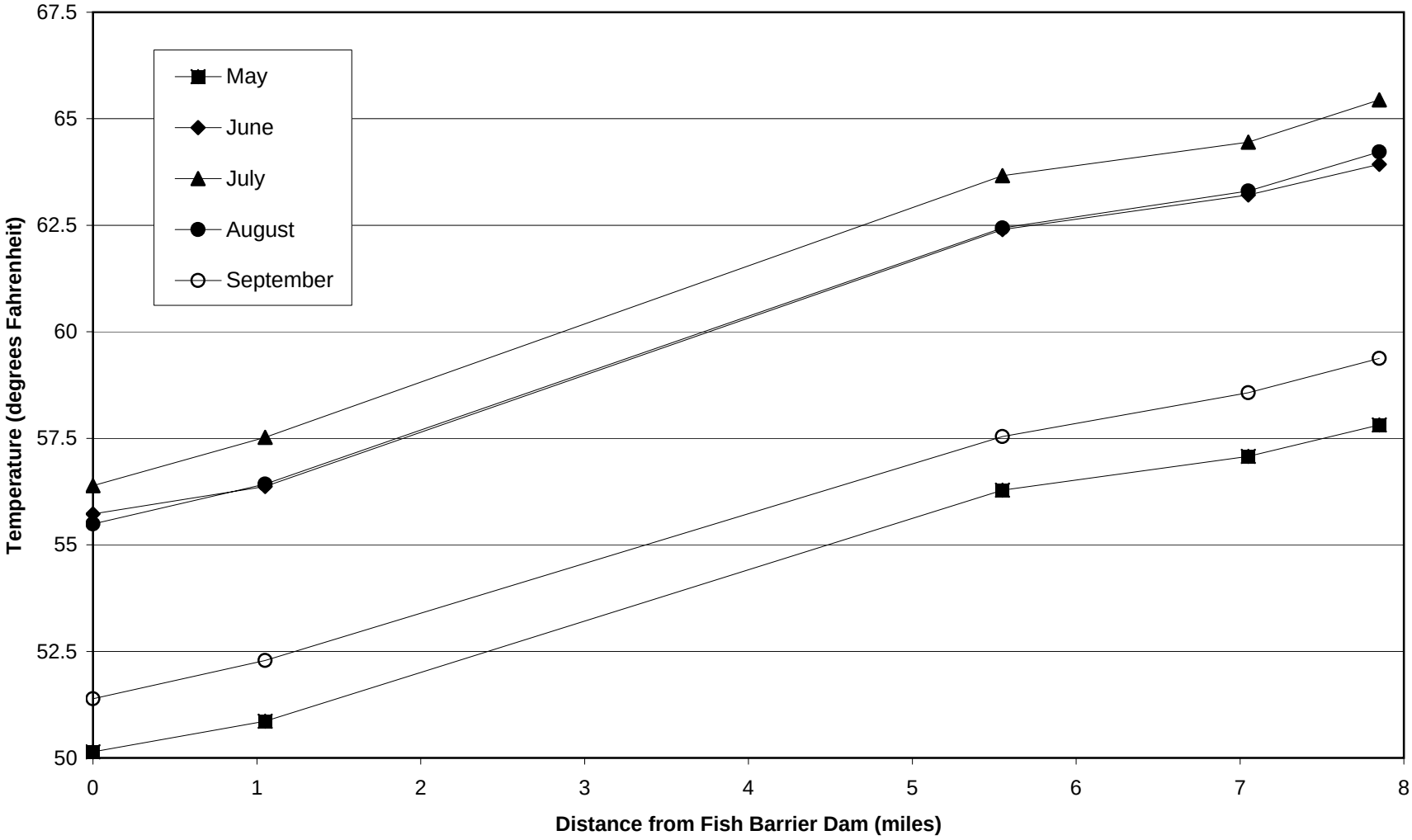


Figure 3. Monthly Maximum of Daily Mean Water Temperatures at Four Locations in LFC, 2002

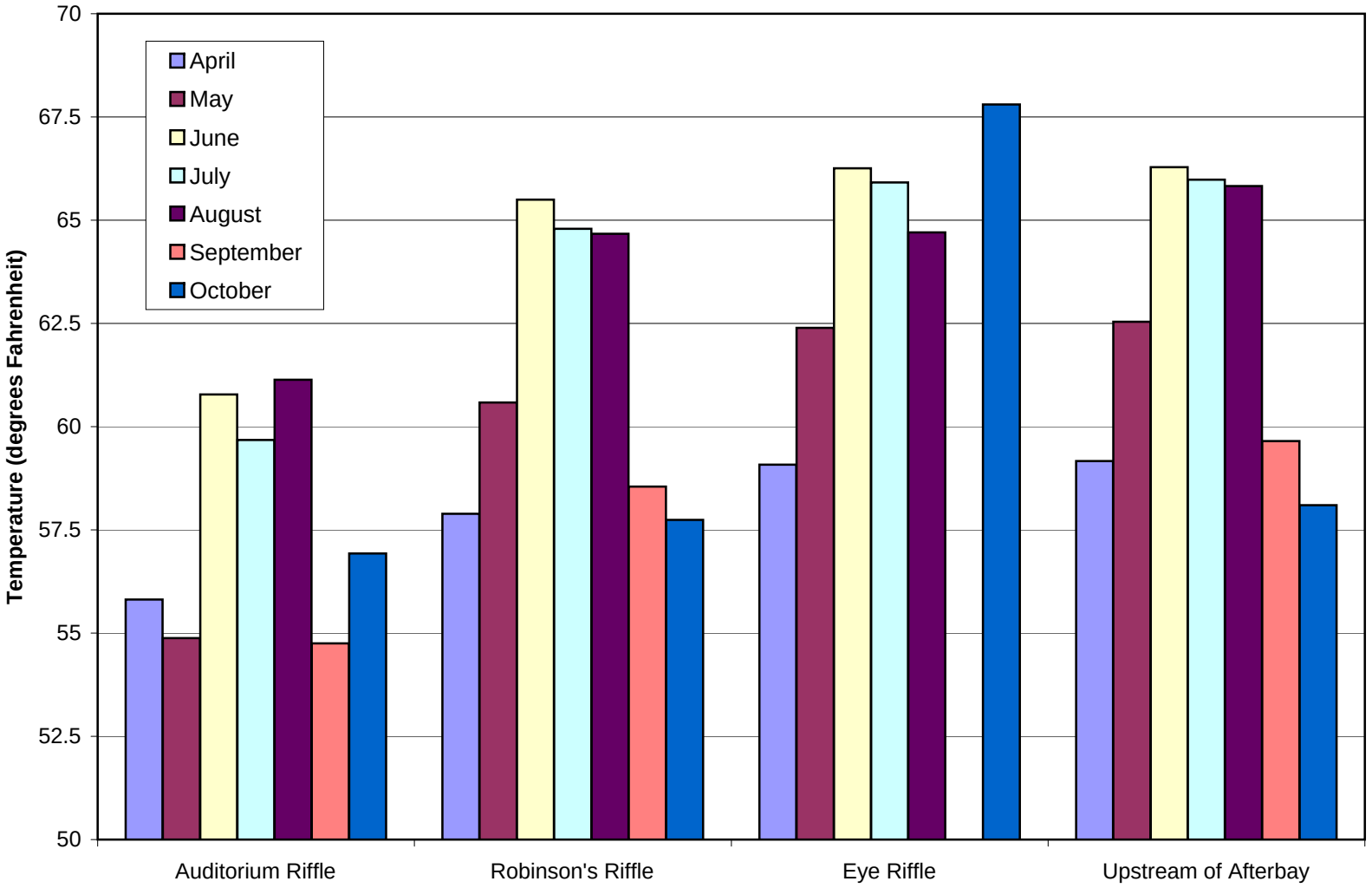


Figure 4. Monthly Maximum of Daily Mean Water Temperatures at Four Locations in LFC, 2003

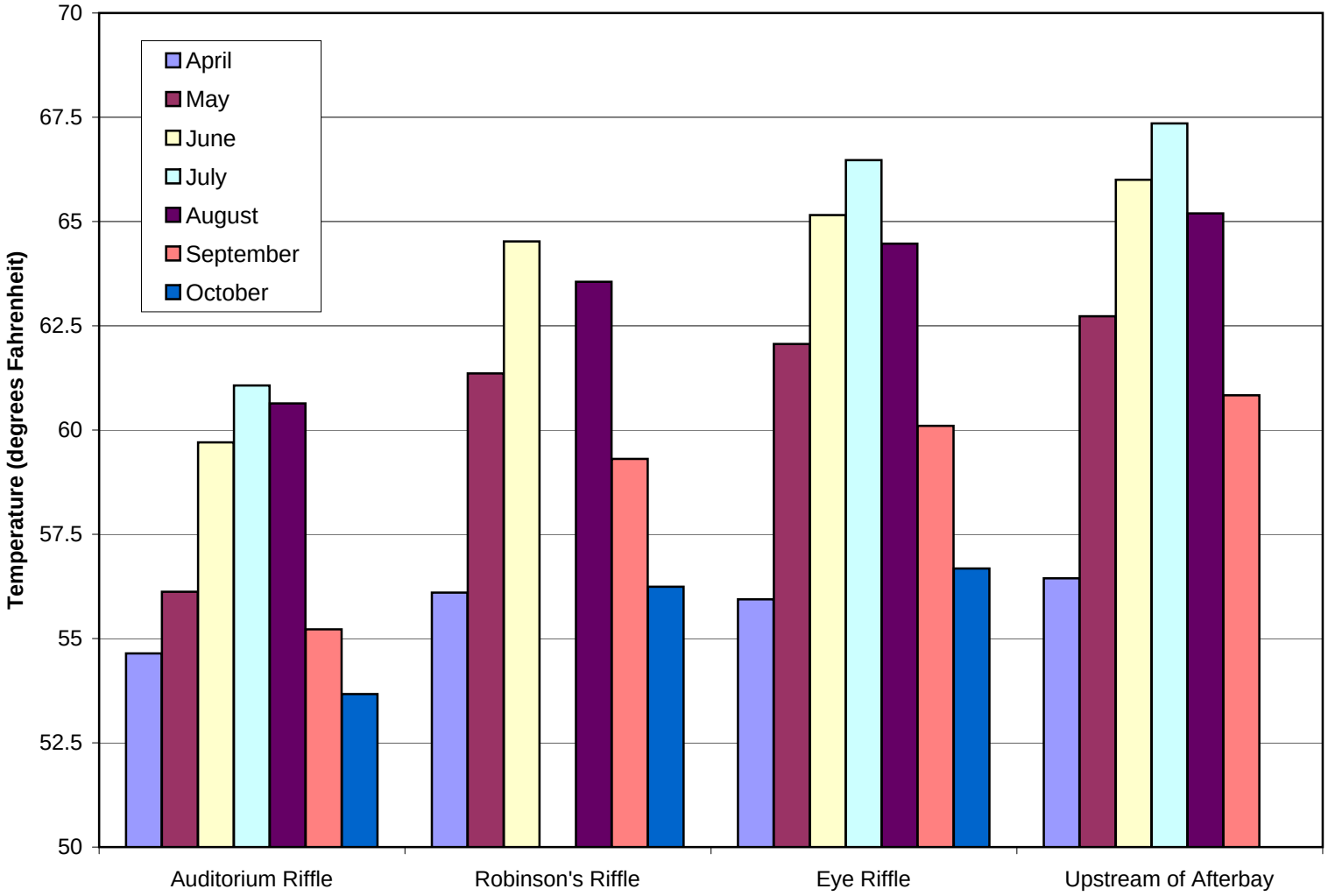


Figure 5. Monthly Averages of Daily Mean Water Temperatures at Four Locations in LFC, 2002

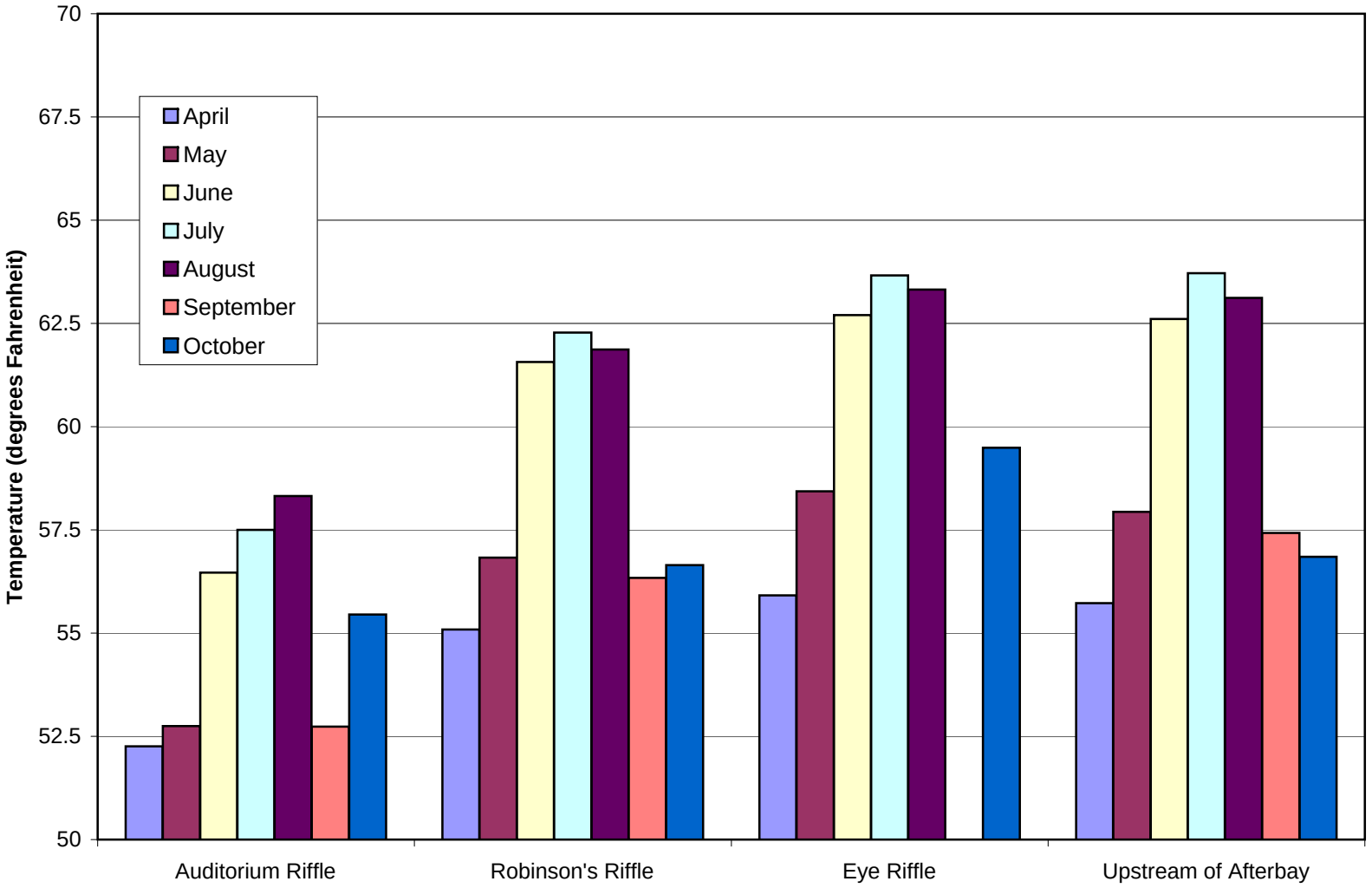
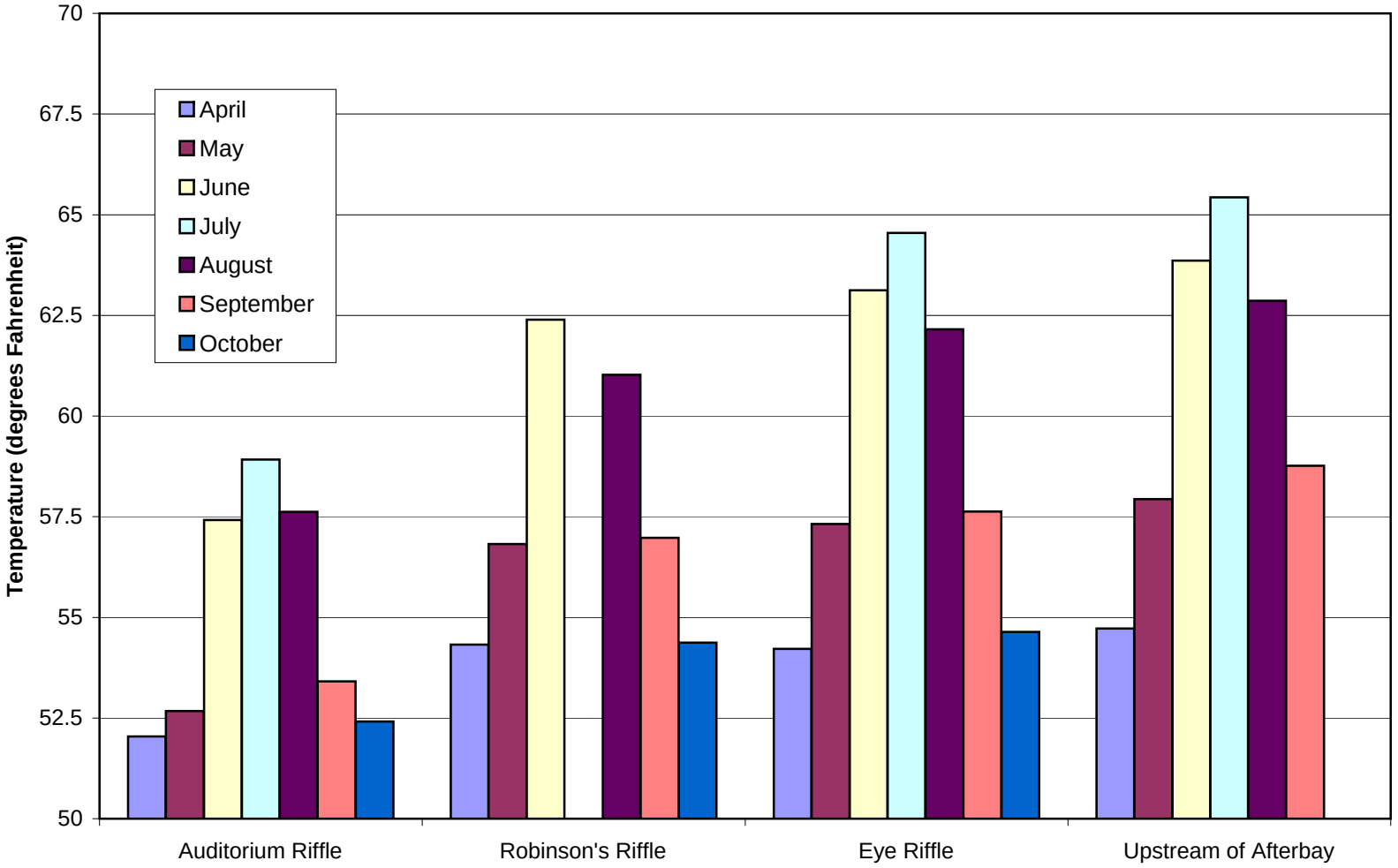


Figure 6. Monthly Averages of Daily Mean Water Temperatures at Four Locations in LFC, 2003



Resource Action: EWG-37 **Task Force Recommendation Category: 2**

Operate the Oroville Facilities to Provide Additional Cold Water in the High Flow Channel of the Feather River for Benefit of Chinook Salmon and Steelhead

Related Resource Actions:

- EWG-27, which proposes to fill, modify, or isolate Robinson Riffle Borrow Pit.
- EWG-34A & EWG-34B, which propose to reduce rates of fish predation on juvenile salmonids by reducing water temperatures.
- EWG-36, which proposes to operate the Oroville Facilities in a manner that would provide colder water in low flow channel of the Feather River for benefit of Chinook salmon and steelhead.
- EWG-87, which proposes to modify the Thermalito Complex facilities in a manner to increase water temperatures in the Thermalito Afterbay and reduce temperatures in the Feather River downstream of the Afterbay outlet for beneficial uses.
- EWG-102, which proposes to provide water temperatures in the lower Feather River that mimic historic (pre Oroville Dam) to help maintain the genetic integrity of the spring-run Chinook salmon.
- E-01, Thermalito Afterbay Water Temperature Improvements: Construct Facilities to Convey Cold Water Directly to TAB Outlet Facility

Date of Field Evaluation: No field evaluation was conducted.

Evaluation Team: Phil Unger and David Sun, reviewed by Brad Cavallo

Description of Potential Resource Action Measure:
This measure would include structural changes and/or changes in operations of the Oroville Facilities to reduce water temperatures in the High Flow Channel of the Feather River (HFC) during certain times of year for the benefit of Chinook salmon and steelhead. The changes in operation would likely include releasing colder water from the reservoir and increasing releases to the Low Flow Channel (LFC). Proposed structural changes would include modifying the canal that conveys water from the Thermalito Forebay to the Thermalito Afterbay to redirect its flow, thereby reducing the residence time of water in the Thermalito Afterbay. The new canal would convey the relatively cold Thermalito Forebay water to the portion of the Thermalito Afterbay nearer the Thermalito Afterbay Outlet, thus reducing temperatures of the water released into the river.

Nexus to the Project:
Water temperatures in much of the lower Feather River are strongly affected by operations of the Oroville Facilities. The Oroville Facilities allow project operators to regulate the depth in Oroville Reservoir from which water is released, the amount of

water released from the reservoir into the river, the amount of water diverted from the LFC of the river through the Thermalito Complex, and the amount of water pumped back into the reservoir from the Thermalito Complex. These operational controls give the operators various degrees of control over water temperatures in the LFC and the upper reaches of the HFC.

The 1983 agreement between the California Department of Water Resources (DWR) and California Department of Fish and Game (DFG), concerning the operation of the Oroville Division of the State Water Project for management of fish and game, established quantitative water temperature criteria for the lower Feather River. In this agreement, the Oroville Project is required to meet quantitative water temperature criteria at two downstream locations: the Feather River Hatchery (FRH) and the LFC at Robinson's Riffle (River Mile 61.6).

The water temperature criteria at the FRH and Robinson's Riffle are the principal water temperature targets controlling Oroville Project operations, but other water temperature objectives and goals occasionally influence project operations and potentially affect water temperatures in the HFC. The 1983 agreement established a narrative water temperature objective for the Feather River downstream of the Thermalito Afterbay outlet. This objective requires water temperatures downstream of the Thermalito Afterbay Outlet that are suitable for fall-run Chinook salmon during the fall (after September 15) and suitable for shad, striped bass and other warmwater species from May through August. This narrative has no direct effect on operations because it is not well defined, but it has encouraged operators to seek opportunities to provide colder water to the HFC during the fall months.

An informal water temperature goal of the Oroville Facilities operators exists for the Thermalito Afterbay. This goal recognizes the need of local rice farmers for warm water temperatures during spring and summer for germination and growth of rice. Most of the rice farmers divert their irrigation water from the Thermalito Afterbay. Water temperature goals to support rice production are a minimum of 65°F during April through mid-May and a minimum of 59°F for the remainder of the growing season. Although DWR is not obligated to meet these goals, Project operators try to accommodate the rice farmers by releasing water as close as possible to the maximum temperature allowed under the FRH criteria. Because most of the water in the Thermalito Afterbay ultimately spills into the HFC of the Feather River, increases in Thermalito Afterbay water temperatures likely produce higher HFC water temperatures.

A recent evaluation conducted by the EWG fisheries technical team of Chinook salmon and steelhead water temperature needs in the Feather River suggests that under current Oroville Project operations, the water temperatures in the HFC of the Feather River are seasonally too warm for salmon and steelhead holding, spawning and rearing. Releases of water into the Feather River from the Thermalito Afterbay contribute substantially to the elevated water temperatures of the HFC.

Potential Environmental Benefits:
Based on recent water temperature conditions and the life histories of spring-run Chinook salmon and steelhead, this Resource Action would be most effective if implemented from April through October. This period includes the rearing period for spring-run Chinook salmon and steelhead and the immigration, holding and spawning period for spring-run Chinook salmon. The EWG fisheries team determined Chinook salmon and steelhead water temperature needs for each life-stage by synthesizing information obtained from the fisheries literature. Both fall-run and spring-run Chinook salmon spawn in the LFC beginning in early September. The upper reaches of the HFC have an abundance of suitable spawning gravels, but limited spawning occurs in the HFC because water temperatures are generally too warm.

The EWG team determined that spawning and egg incubation water temperature requirements for Chinook salmon are no more than 56^{o}F or 58^{o}F (the two values reflect minor differences in the set of literature sources used for deriving the critical temperature estimates). During 2002 and 2003, the maximum September daily average water temperatures in the HFC upstream of Honcut Creek ranged from about 63 ^{o}F to 67^{o}F (**Figure 1**), and the mean September daily average water temperatures ranged from about 61 ^{o}F to 63^{o}F (**Figure 2**). These results indicate that a fairly substantial reduction in water temperatures in September would be required to provide suitable spawning conditions for the Chinook salmon in the HFC. The analysis of water temperatures is limited to the HFC upstream of Honcut Creek because this portion of the HFC has the best spawning habitat conditions and because, realistically, modifications to the Oroville Facilities or their operations would be unable to affect water temperature further downstream.

Steelhead begin spawning about December, but continue spawning until about April, and egg incubation may continue through May. The EWG fisheries technical team determined that spawning and egg incubation temperature requirements for steelhead are 52^{o}F and 54^{o}F (again, the two values reflect differences in the set of literature sources used for estimates). During 2002 and 2003, the maximum and mean daily average water temperatures in the HFC were consistently higher than the steelhead spawning and egg incubation temperature requirements (**Figure 1 and 2**). Substantial reductions in water temperatures would be required to provide suitable conditions for steelhead egg incubation.

Implementing the Resource Action during the summer months could benefit spring-run and fall-run Chinook salmon. Spring-run adults hold in pools in the lower Feather River from late spring through summer. Fall-run migrate upstream in late summer and hold more briefly. The EWG fisheries technical team determined that upstream migration and holding temperature requirements for adult spring-run and fall-run Chinook salmon are 60^{o}F and 64^{o}F (the two values reflect differences in the set of literature sources used for estimates). During the summer, and especially in June, the mean and

maximum daily average water temperatures at the five locations in the HFC were generally higher than these temperature requirements (**Figures 1 and 2**). Therefore, reducing water temperatures from June through August would likely benefit migrating and holding Chinook salmon, particularly spring-run Chinook salmon, by providing additional holding habitat in the upstream section of the HFC.

Figure 1. Monthly maximum of daily mean water temperatures at five locations in HFC in 2002 (top) and in 2003 (bottom). Note: DS = downstream.

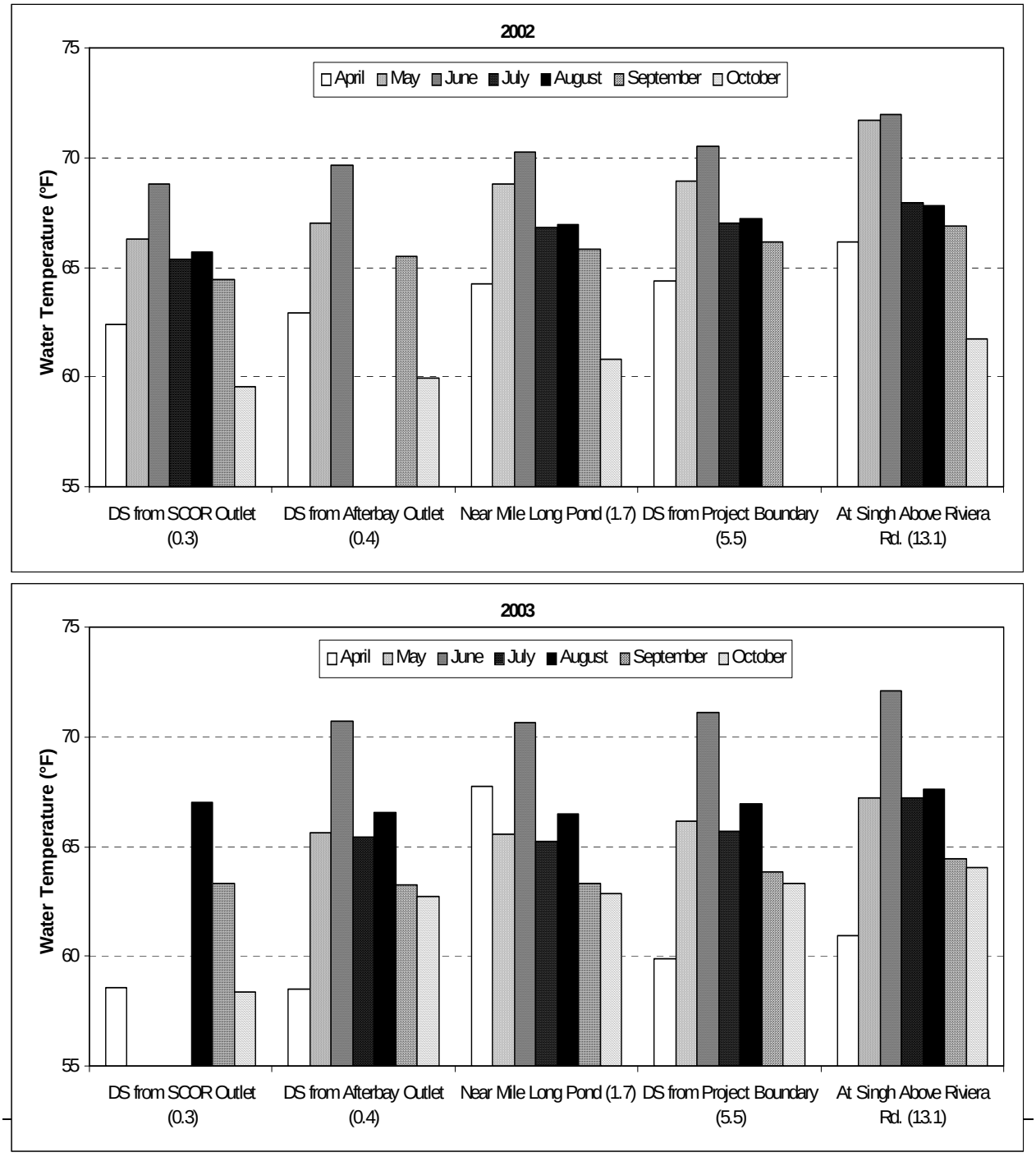
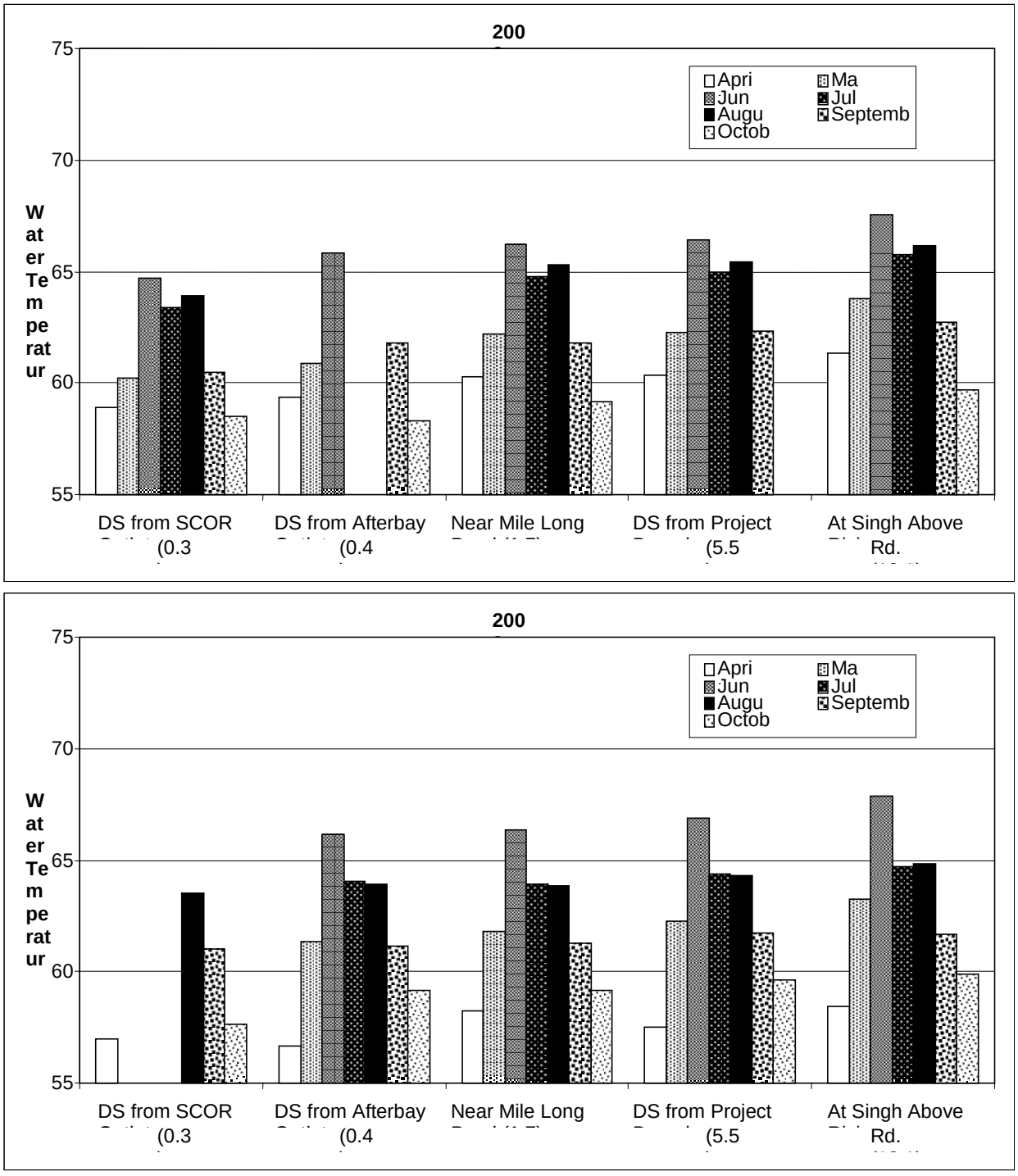


Figure 2. Monthly average of daily mean water temperatures at five locations in HFC in 2002 (top) and in 2003 (bottom). Note: DS = downstream.



Potential Constraints:
The most significant potential constraint on this measure is the limited volume of Oroville Reservoir's cold-water pool. The limited amount of cold water available in the reservoir restricts how much and for how long water temperatures in the LFC and HFC could be reduced. This constraint would be particularly significant in dry and critically dry water years. Note that the FRH water temperature criteria limit the amount of reduction in water temperatures which are allowed to be released from Lake Oroville.

A biologically important constraint on reducing water temperatures in the HFC is the potential for adverse effects on salmonids in the LFC. A likely means to reduce water temperatures in the HFC would be to release more and colder water to the LFC. However, water that is too cold would adversely affect egg development and growth of juveniles, while flows that are too high would reduce habitat quality for rearing juveniles.

Another important constraint is the loss of power generation through the hydroelectric facilities that would potentially accompany implementation of this measure. Operations that can be used to reduce water temperatures in the HFC include increasing flow releases to the LFC, reducing pump-back and peaking operations, and opening the Oroville Dam river valve. These actions would typically result in varying degrees of losses in hydroelectric power generation.

This measure could also be constrained by regulatory requirements. The narrative objective for water temperatures in the HFC below the Thermalito Afterbay river outlet requires water temperatures that are suitable for shad, striped bass and other warmwater species from May through August. Reducing spring and summer water temperatures in the HFC could make it difficult to meet this objective. Finally, measures to reduce water temperatures in the HFC are also potentially constrained by the need to supply rice farmers with warm water during spring and summer and by the goal to provide suitable warm water for recreational activities.

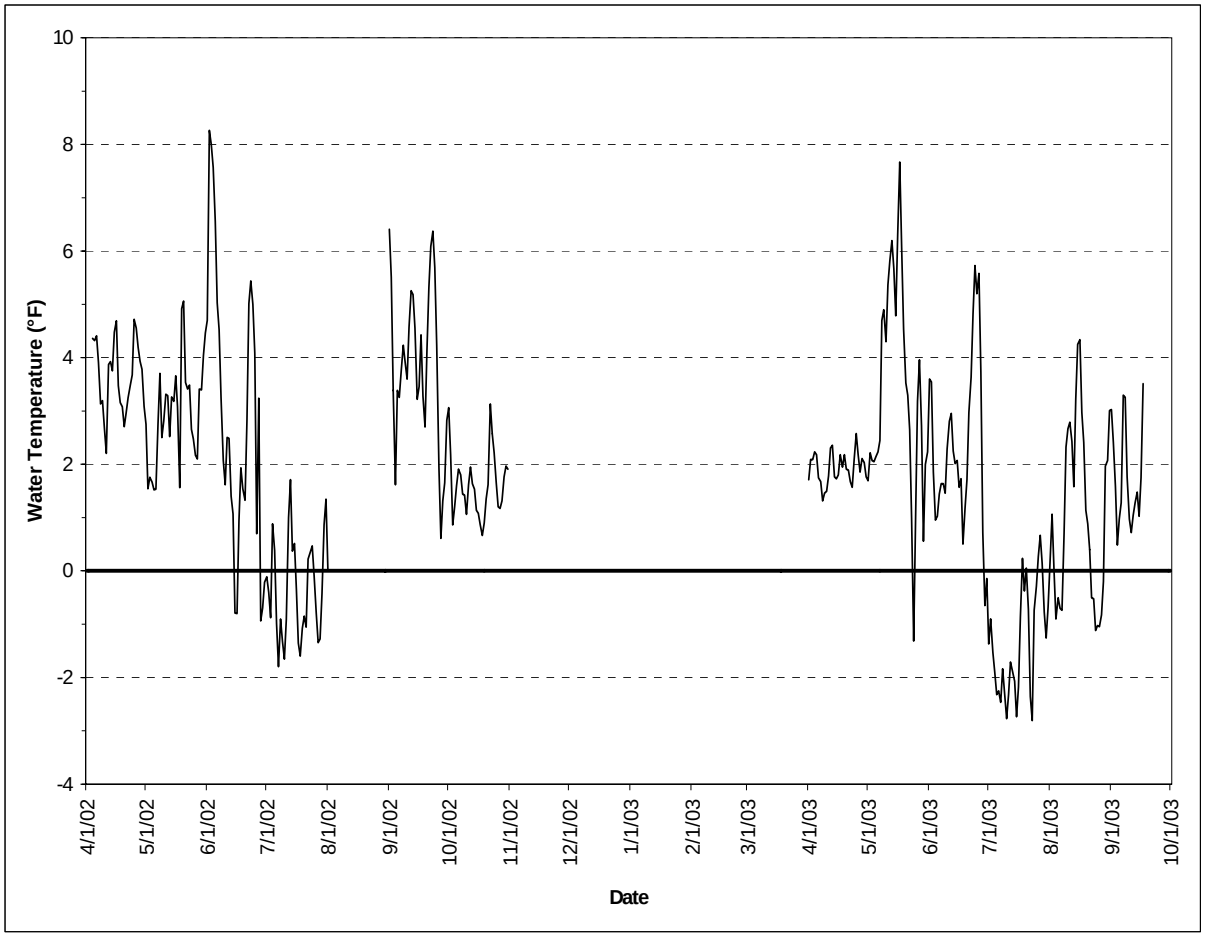
Existing Conditions in the Proposed Resource Action Implementation Area:
The portion of the lower Feather River that is the focus of this Resource Action is the upstream section of the HFC, extending about 14 miles from the Thermalito Afterbay Outlet to Honcut Creek. The minimum flows and the water temperature targets in the HFC are established by a 1983 agreement between DWR and DFG. The instream flow requirements are 1,700 cfs from October through March and 1,000 cfs from April through September for wetter years (> 55% of normal runoff), and 1,200 cfs for October through February and 1,000 cfs for March through September for drier years. As previously described, the water temperature must be suitable for fall-run Chinook salmon after September 15, and they must be suitable for shad, striped bass, and other warmwater species, from May through August.

Spring and summer water temperatures in the HFC are typically quite a bit warmer than those in the LFC in large part because of the large volumes of relatively warm water

released to the HFC from the Thermalito Afterbay Outlet. Water temperatures in the Thermalito Afterbay are relatively high because water moves more slowly through the Thermalito Complex, and especially the Afterbay, than through the LFC and is subject to greater atmospheric warming. The contribution of the Thermalito Afterbay Outlet inflow to the total flow of the HFC is typically greater than that of the LFC flow.

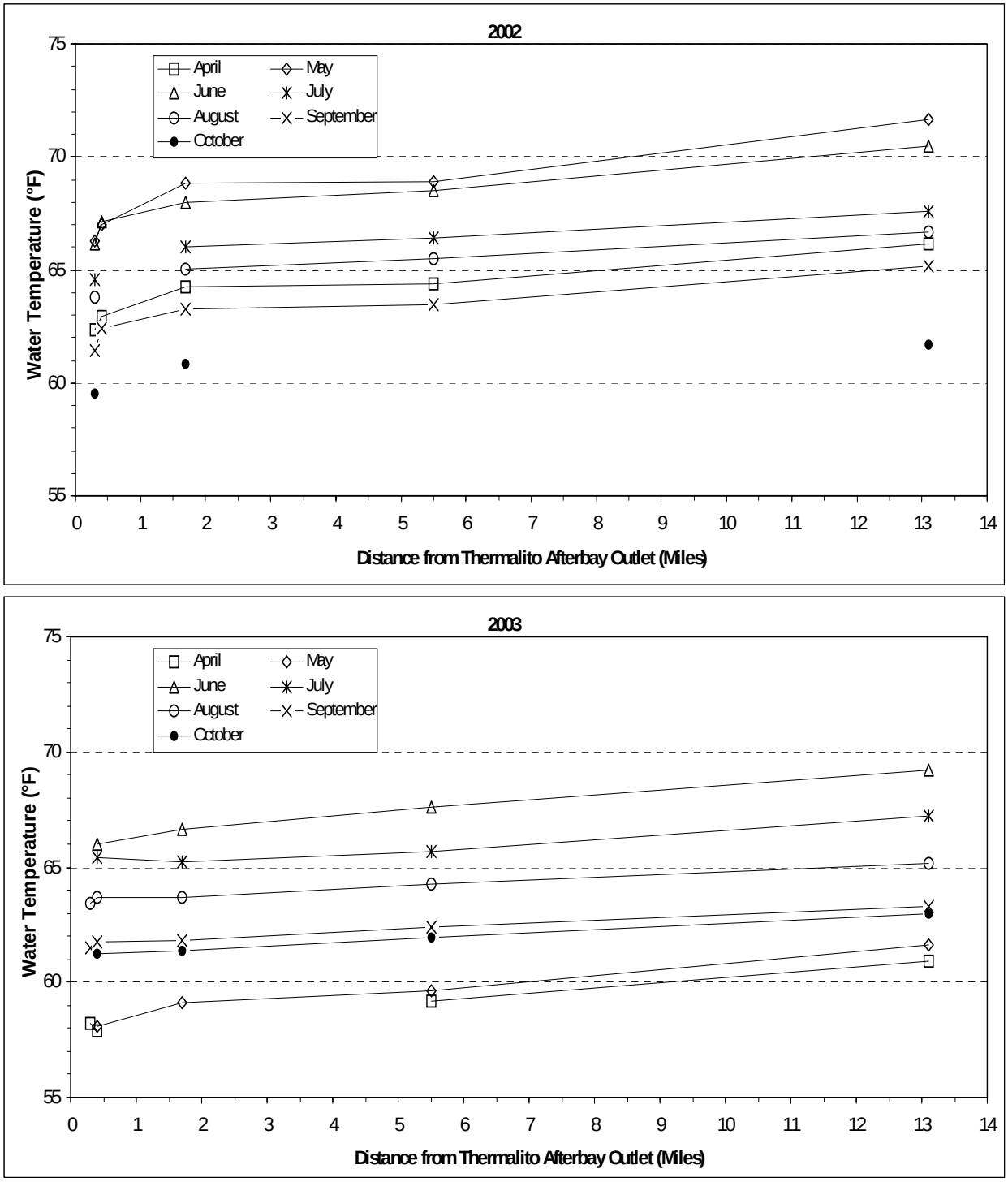
The releases of large flows with relatively high water temperatures from the Thermalito Afterbay Outlet typically results in a sharp thermal gradient from the downstream end of the LFC to the upstream end of the HFC. Water temperatures in the HFC just downstream of the Afterbay Outlet are often several degrees warmer (as much as 8^{o}F in early June 2002) than temperatures in the lower part of the LFC (upstream of Thermalito Afterbay Outlet), particularly in the late spring and early summer (**Figure 3**). This change in water temperature may be stressful for migrating fishes, but also elevates predation risk because of the increased abundance of piscivorous bass and Sacramento pike minnow.

Figure 3. Differences in daily average water temperature between sites downstream and upstream of the Afterbay in 2002 and 2003.
Note: Negative number denotes cooler downstream water temperature.



Beyond the influence of the Thermalito Afterbay Outlet, downstream warming in the HFC is relatively low, at least as compared to that in the LFC. During late spring and summer in 2002 and 2003, water temperatures in the HFC warmed a maximum of less than 6^{o}F over approximately 13 miles between the Thermalito Afterbay Outlet and Honcut Creek (**Figures 4**). In the LFC, water temperature increased as much as 9^{o}F over the 8-mile reach of the LFC (EWG 36). The reduced warming rate in the HFC is attributable to its higher flows and to the fact that the HFC water temperatures are usually more nearly in equilibrium with atmospheric temperatures than the LFC water temperatures. Patterns of warming in the HFC were similar from month to month within each year.

Figure 4. Water Temperatures in HFC during days of maximum warming in 2002 (top) and in 2003 (bottom).



Design Considerations and Evaluation:
As previously indicated, some measures to significantly reduce water temperatures in the HFC would potentially affect habitat conditions in the LFC adversely. Results of the modeling simulations currently being conducted by Engineering and Operations modelers will be used to develop specifics of how different project operations would affect water temperatures and flows in both the HFC and the LFC.

Implementing this Resource Action by modifying the conveyance system for water entering the Thermalito Afterbay would involve a number of complex design considerations. These will be addressed in EWG 87, which more directly addresses water temperature conditions in the Thermalito Afterbay.

The effectiveness of this measure would be evaluated by comparing water temperatures measured at several locations in the lower Feather River before and after implementing the measure. The comparisons would use water temperature modeling to adjust for differences in atmospheric conditions and other potentially confounding variables in making the comparisons. Water temperature data currently being collected in the lower Feather River will provide the information on water temperatures before implementing any changes in project operations.

Synergisms and Conflicts:
This Resource Action is compatible with Resource Action EWG-36 and EWG-102, which share with EWG-37 the resource goal of providing desirable water temperatures for coldwater fish. By benefiting coldwater fishes, the Resource Action would likely enhance recreation in the HFC, providing increased summer angling opportunities for trout and Chinook salmon. This Resource Action would likely reduce the steep thermal gradient between the HFC and the LFC and thereby improve upstream passage and habitat conditions for anadromous salmonids, which are resource goals of many of the proposed resource actions. The colder water that would result from this measure might also help reduce predation on juvenile salmonids because the colder water would reduce metabolic rates of the fish predators in the HFC, and thereby potentially reduce their feeding rates. Reduced predation on juvenile salmonids is the resource goal for Resource Action EWG-35A, EWG-35B and EWG- 27.

This Resource Action would potentially conflict with a number of resource goals. These include providing warmer water to Thermalito Afterbay for agriculture (e.g., EWG-87), increasing production of coldwater fishes in the reservoir, and enhancing water-contact recreational opportunities in the lower Feather River. However, to the extent that more water is diverted through the LFC rather than through the Thermalito Complex, or that the cold water entering the Thermalito Afterbay is conveyed more directly to the Thermalito Afterbay Outlet, this Resource Action also has the potential to allow warmer waters for agricultural diversion from the Thermalito Afterbay (EWG-87). Depending on

the methods used to reach desired water temperatures, this Resource Action could also have considerable costs in terms of lost power generation.

Uncertainties:
Important uncertainties related to this Resource Action include:

- Whether the amount of water in Oroville Reservoir's cold-water pool during dry and/or critically dry years would be sufficient to effect the proposed reductions in water temperatures, particularly during late summer and fall, and how a reduction in the volume of the cold-water pool would affect the cold-water fisheries of the reservoir.
- Whether the Resource Action could be implemented without adversely affecting salmonids in the LFC.
- Whether the Resource Action could be implemented without conflicting with DWR agreements or goals, including the FRH water temperature criteria, the agreement to accommodate water temperature needs of rice farmers, and the agreement to provide water temperatures downstream of the Thermalito Afterbay outlet from May through August that are suitable for shad, striped bass and other warmwater species.
- The amount of revenue that would be lost because of changes in power generation.

Cost Estimate:
The principle costs of this measure would be construction costs associated with modifying the conveyance system for water entering the Thermalito Afterbay and lost revenues associated with the changes in power generation (including reduced generation and changes in generation peaking). Additional costs would come from water temperature monitoring to evaluate the effectiveness of the measure and to ensure compliance with any new water temperature requirements.

Recommendations:
Before implementing this measure, better information is needed from water temperature modeling simulations. These evaluations should provide useful insights on the feasibility of the measure in light of the potential conflicts and limitations.

Resource Action: EWG-50 **Task Force Recommendation Category: 2**

Maintain the Cold Water Fishery Program in Lake Oroville

Date of Field Evaluation: No field evaluation was conducted

Evaluation Team: Eric See and Michael Manwaring

Description of Potential Resource Action Measure:
This proposed Resource Action would constitute a continuation of an existing Department of Water Resources (DWR) program, that began with a September 22, 1994 FERC order. This FERC order required DWR to implement its Revised Recreation Plan for the Lake Oroville State Recreational Area (LOSRA), and one of the components of that recreation plan was for DWR to stock Chinook salmon in Lake Oroville, and conduct studies on this stocking program to develop optimum stocking rates for the reservoir. Once completed, DWR was to send the results of these studies to FERC along with recommendations for stocking coldwater fish in Lake Oroville. DWR sent these recommendations to FERC in early 2000, and subsequently had to suspend the fish stocking activities due to concerns related to fish disease. DWR's correspondence to FERC indicated that additional fish stocking studies would be conducted, and FERC would be notified of new stocking recommendations when they became available. On February 27, 2004, FERC issued an order requiring DWR to confer with DFG, NOAA Fisheries, USFWS, and other regulatory agencies as well as local public governmental and non-governmental organizations to develop a coldwater fish stocking plan each year through the end of the existing license.

Related Resource Actions:
There are other Resource Actions that are either similar to or otherwise related to this measure:

- EWG-31, that proposes to enhance fish habitat in Lake Oroville, primarily in the fluctuation zone of the reservoir.
- EWG-45, that proposed to create trophy salmonid stocking program in Afterbay similar to trophy stocking program in Lake Oroville.
- EWG-47, that propose create trout stocking program in suitable OWA ponds.
- EWG-48B, which proposes to stock bass in Lake Oroville.
- EWG-97A/B, that proposes to pass Feather River salmonids into the tributaries above Lake Oroville (related because some of these smolts would migrate into the Lake Oroville coldwater fishery).

Nexus to the Project:
Maintaining a cold water fishery program in Lake Oroville is part of a FERC order issued to DWR on September 22, 1994. This order required DWR to implement its Revised Recreation Plan for the LOSRA, and one of the components of that recreation plan was

for DWR to stock fish in Lake Oroville, and conduct follow up studies related to stocking rates for the reservoir.

Potential Constraints:
The most critical constraint with this action is finding an adequate stock of coldwater fish to plant into Lake Oroville. Due to fish disease concerns at the FRH and Feather River below Lake Oroville, DFG currently will only allow coho salmon to be stocked. NOAA Fisheries has expressed concerns that coho salmon, which are not native to the Central Valley, may escape and compete with ESA listed Central Valley salmonids. They are also concerned about the potential genetic mixing of the Lake Oroville coho salmon with California coastal coho stocks which are also ESA listed.

Design Considerations and Evaluation:
This action would involve implementing the fish stocking recommendations developed under the current FERC license during 2004 (and possibly 2005) by DWR, DFG, USFWS, and NOAA Fisheries. Stocking recommendations need to be periodically reviewed to ensure they are meeting the goals of the recreational fishery at the reservoir, so this action would be implemented on a 5-year basis (these goals are part of the stocking recommendation development process). Stocking would be accomplished in cooperation with the DFG, using the DWR-funded Feather River Hatchery, as well as possibly other hatcheries that are funded by DFG. Eggs may need to be purchased by DWR that would supply the Feather River Hatchery and/or other DFG hatcheries.

Cost Estimate:
According to DWR personnel, the approximate annual costs for this measure would be $60,000 for fish stocking, and $5,000 for monitoring. There may also be additional costs related to more extensive monitoring (e.g., Coded Wire Tags), as well as activities associated with developing a more desirable stock of coldwater fish, such as a broodstock program using a California strain of coho, or fish sterilization so escapees could not spawn with native coho.

Recommendations:
This Resource Action would constitute a continuation of an existing DWR fish stocking program, that is required under the September 22, 1994 FERC order. It is recommended that this measure be further investigated by DWR to determine the appropriate course of action required to comply with the existing FERC order for the coldwater fishery program in Lake Oroville.

Resource Action: EWG-106 **Task Force Recommendation Category:** 2

IMPLEMENT A COMPREHENSIVE MARKING/TAGGING PROGRAM AT THE FEATHER RIVER HATCHERY

Related Resource Actions:

- This resource action covers several marking/tagging related actions proposed by members of the Feather River Hatchery Technical Team.
- EWG-107, development of adaptive management plan for operations of the Feather River Hatchery.

1. Resource Action Description:

Develop and implement an appropriate marking/tagging program for all anadromous fish produced and released by the Feather River Hatchery (FRH). Tagging programs are essential to evaluating the effectiveness and impacts of hatchery operations. The FRH tagging program would rely on coded wire tags, otolith thermal marks, fin clips, and/or passive integrated tags. The specific attributes of the tagging program will be guided by: (1) the constant fractional marking program currently being developed by California Department of Fish Game (via CALFED contractors), (2) FRH objectives and issues identified through the FRH adaptive management program (EWG-107), (3) the need to provide statistically reliable estimates of FRH contribution to ocean/inland fisheries, out-of-basin straying, and spawning populations, (4) the need to provide visual identification of hatchery origin steelhead and spring-run Chinook, and (5) the need to provide statistically reliable estimates of proportions of wild, natural origin salmon and steelhead. This program would continue as long as the FRH is producing anadromous salmonids. The program would be subject to ongoing review by annual meetings of an interagency advisory committee, and would be subject to a thorough written review and critique every five years.

2. Project Nexus

Under the FERC license the FRH will continue to be a mitigation feature of the State Water Project's Oroville Facilities. Under the FERC agreement and through the ESA consultation process, the Department of Water Resources (DWR) may be required to better understand the impacts of hatchery (and project) on natural salmonid populations. Without the ability to distinguish hatchery fish from naturally spawning fish in the ocean and inland fisheries and on the spawning grounds with an acceptable degree of statistical reliability, it may not be possible to assess hatchery (or project) impacts on natural salmonid populations.

3. Potential Environmental Benefits

The ability to distinguish hatchery from naturally spawning fish will allow biologists and managers to better identify hatchery impacts and modify

operations to minimize adverse effects. A marking program is thus a critical part of the adaptive process that DWR and other resource agencies would need to integrate hatchery operations into an overall Central Valley salmon recovery and conservation program.

4. Potential Constraints

The major constraints are institutional and financial. Implementing this program would require critical review of potential tagging program attributes. Different approaches to tagging should be considered through an adaptive process including DWR staff and members of an interagency advisory team. The tagging program should be evaluated and recommendations made to modify the marking program as needed to meet data needs.

An appropriate program for tag recovery and analysis of resulting data would also be required. Staff for analysis and management of a tagging program will also be covered by EWG-107. The necessary recovery programs would be funded separately (and are already partially funded by DWR). It is not possible at this time to estimate the additional incremental costs for these recovery programs.

5. Existing Conditions

For about the past 10 years, a variable fraction of FRH salmon was coded wire tagged and adipose clipped, with the fraction generally 10 percent or less. Beginning with the 2001 cohort, all spring Chinook are being tagged and all steelhead are being adipose fin clipped (but not tagged). Prior to 1994 few FRH salmon were tagged.

6. Design Considerations

Other than determination and design of the sampling program itself, implementing this proposed action would also require some physical design considerations at the FRH. First, one must consider how the tagging operations are to be situated on the hatchery grounds. The existing tagging trailer would have to be evaluated to determine if it can meet the tagging needs of new program – both in terms of the numbers of fish to be tagged and the timing of the releases needed to meet experimental and operational goals. Plumbing, electrical and fish holding needs must be considered in this evaluation. Hatchery raceways would need modifications to have sufficient flexibility to segregate groups of tagged fish. Also, a more permanent tag sample storage facility should be considered. An alternate strategy would be to establish an affiliate tag processing lab at the FRH where samples from the Feather and perhaps Yuba Rivers could be stored, the tags extracted and the tags decoded.

7. Synergism and Conflicts

This action is synergistic with all actions designed to make operation of the FRH more environmentally sensitive, while still meeting DWR's mitigation responsibilities for construction and operation of the Oroville complex. There are no apparent conflicts with other proposed resource actions or existing hatchery operations.

8. Uncertainties

Given the adaptive nature of the proposed program the structure of the final program is uncertain. However, the program would be consistent with the goals identified earlier in the Resource Action Description.

The decision making process for the advisory team and the adaptive management component of this program has not been established. However, decision making practices for this effort will follow protocols established for other adaptive management programs that will be developed as part of the relicensing settlement.

9. Cost Estimate

Environmental Scientist staff time would be required to perform the necessary review, data analysis, report writing and coordination. We expect that this staff time would amount to approximately $60,000 annually (this estimate does not include time of existing DFG hatchery staff). Costs of the tagging program itself are difficult to estimate given the proposed adaptive development of the tagging program. However, if coded wire tag constant fractional marking program were to be implemented we could expect tagging costs to be approximately $800,000 per year. This assumes tagging about 5 million smolts at a cost of 16 cents per tag (tag purchase plus application) and assumes that the existing tagging trailer and contracting process are adequate. Additional equipment (e.g. tag injectors) required to place the tags can be expected to cost an additional $50,000 per year. These costs would occur annually for as long as the FRH continues to produce anadromous salmonids.

10. Recommendations

Development of marking/tagging program that meets program objectives is essential to future operation and management of the FRH.

Resource Action: EWG-107 **Task Force Recommendation Category:** 1

IMPLEMENT A COMPREHENSIVE ADAPTIVE MANAGEMENT PROGRAM FOR FEATHER RIVER HATCHERY

Related Resource Actions:

- This is an omnibus resource action intended to address numerous concerns about operations and practices of the FRH.
- EWG-107 is related, but is specific to development of a tagging program.

1. Resource Action Description:

The goal of this program is to provide a framework for ongoing evaluation and improvements in operations of the Feather River Hatchery (FRH). This resource action would create a program to adaptively manage FRH practices to enhance benefits while assessing and minimizing negative impacts.

The evaluation of FRH practices would begin with a rigorous review of management and production goals. In addition, this review would include an assessment of: 1) release strategies (including timing, size at release and release location), 2) straying impacts, 3) genetic integrity of FR stocks, 4) marking/monitoring program design and effectiveness, 5) interactions with wild fishes, 6) diseases within and propagated by FRH, and 7) rearing practices, including exposing hatchery fish to natural conditions (e.g. add cover and predators to hatchery raceways) . An adaptive approach to addressing these issues is necessary because goals of the FRH are likely to change, and because of uncertainty regarding necessary changes in hatchery operations. A long-term, adaptive approach is also sensible given that it will take several generations (with at typical 3-4 year age at maturity) to observe effectiveness of management actions. DWR would provide necessary staff to evaluate these issues, implement necessary changes, and coordinate findings/decisions with a FRH advisory committee. Specific tasks, studies and changes in hatchery practices would be developed through products of SP-F9 reports and early meetings with the FRH advisory committee. This program would continue indefinitely, or as long as the FRH is producing anadromous salmonids. The program would be subject to ongoing review by annual meetings of the interagency advisory committee, and would be subject to a thorough written review and critique every five years.

2. Project Nexus

Under the FERC license the FRH will continue to be a mitigation feature of the State Water Project's Oroville unit, albeit likely with some significant operational changes. Under the FERC agreement and through the ESA consultation process, DWR will be required to better understand mitigation success and the impacts of hatchery (and project) on natural salmonid populations. In terms of numbers of fish, the hatchery has done an admirable job of mitigating the habitat losses – especially with fall Chinook. However the hatchery has had some

undesirable impacts including negative interactions with wild salmonids, obscuring the genetic and phenotypic differences between fall and spring Chinook and release practices have increased straying of Feather River Chinook to the other Central Valley streams resulting in genetic introgression with other Central Valley stocks.

3. Potential Environmental Benefits

Ongoing evaluation of the effects and benefits of hatchery operations should result in a more environmentally friendly mitigation hatchery and salmonid populations that have increased overall fitness. As part of a broader Central Valley salmonid restoration/science program, the evaluation program is essential to recovery to listed salmonid runs.

4. Potential Constraints

The potential constraints are institutional and financial, but also include coordination with other similar efforts through the Central Valley. Funding needs may include creating new environmental scientist positions (2) to carry out the hatchery evaluation program. This will increase overall costs of the SWP operations. Hiring new staff may be difficult given current state budget crisis related hiring restrictions. Integration within Valley-wide hatchery/salmon science system will also be a challenge. To be most effective, the FRH program should be an integral part of a Valley-wide system. This management system includes coordination with other Central Valley hatcheries and integration with salmon inland/ocean salmon marking and monitoring programs.

5. Existing Conditions

With the exception of the current FERC related process, there is no concerted on-going effort on part of DWR or DFG to evaluate the effect of the Feather River Hatchery. This effort is needed to help protect salmon and steelhead resources and to prepare for subsequent FERC licenses and compliance with state and federal endangered species acts.

6. Design Considerations

No physical design considerations are associated with this resource action.

7. Synergism and Conflicts

This action is synergistic with all actions designed to make operation of the FRH more environmentally sensitive, while still meeting DWR's mitigation responsibilities for construction and operation of the Oroville complex. There are no apparent conflicts with other proposed resource actions or existing hatchery operations.

8. Uncertainties

Given the adaptive nature of the proposed program future required changes to the FRH are uncertain. Similarly, costs for future programs recommend by this adaptive approach are unknown.

The decision making process for the advisory team and the adaptive management component of this program has not been established. However, decision making practices for this effort will follow protocols established for other adaptive management programs that will be developed as part of the relicensing settlement.

9. Cost Estimate

Additional environmental scientist staff time will be required to perform the hatchery evaluation proposed in this resource action. We expect this effort would require two environmental scientist positions at an approximate annual cost of $150,000. Some additional costs not included in this estimate may be required for office equipment, travel and training. These costs would occur annually for as long as the FRH continues to produce anadromous salmonids.
Additional costs may also be associated with changes in hatchery practices which may be recommend by review and adaptive management. Unfortunately there is no way to estimate these costs at this time.

10. Recommendations

Development of an adaptive hatchery evaluation program is essential to successful management of the FRH. This program should be given a very high priority.